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AN ATTEMPT TO CORRELATE THE MARINE WITH THE NON-MARINE FORMATIONS OF THE MIDDLE WEST.

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It is the purpose of this paper to call attention to and to direct investigation along certain lines by which, as it appears to the present writer, we may be able eventually to reach a better understanding regarding the relative age of the various Jurassic and Cretaceous horizons of the Middle West.

It has doubtless frequently occurred to every geologist and paleontologist who has conducted investigations relating to the formations referred to in the title of this paper that marine, terrestrial, fresh and brackish water conditions must have prevailed simultaneously and continuously over extensive areas in our Middle West throughout that long period in middle and late Mesozoic times during which sea and land alternately held dominion over considerable portions of that region. Nevertheless, no serious attempt has been made to correlate the various marine and non-marine deposits with one another. In our geological text-books and in numerous monographs, memoirs and less pretentious papers relating to the geology and paleontology of this region these various formations are described in the text and represented in the accompanying geological columns as occurring in regular sequence one above the other, and the impression is given that where a marine formation is superimposed by a non-marine or *vice versa* the over-

lying bed belongs to a separate and distinctly more recent age than the underlying deposit. To the present writer this assumption appears in not a few instances to be quite unwarranted, the burden of evidence when carefully considered being in favor rather of considering the two formations, largely at least, as contemporaneous in origin, marine and non-marine conditions having existed simultaneously not over the same but over adjacent regions, each giving origin to its characteristic deposit and the marine beds appearing above or below the non-marine according to whether the sea was encroaching upon or receding from the land-mass during the period of their deposition.

The physical conditions that prevailed during the deposition of any geological formation or series of formations and the manner in which a marine deposit is replaced by a non-marine or *vice versa*, are best understood by a study of those regions where, under existing conditions, similar deposits are in process of formation. As an illustration let us consider the conditions that at present prevail almost continuously along our Atlantic coast from Florida to Long Island. Throughout this entire coast line a broad and little elevated coastal plain extends inland from the sea to the eastern foothills of the Appalachian Mountains, while to the eastward of this coast line there lies an equally broad and gently inclined continental plateau at present but little submerged beneath the sea. The eastern limit of this submerged portion of the continental plateau may be regarded as having formed the coast line of the continent at some former period in our earth's history, when the eastern portion of this continent stood at a greater elevation than at present. It was during this earlier period of increased elevation that the Appalachians suffered most from denudation and that the coastal plan, together with the submerged continental plateau, were formed, not as at present differentiated, but as a continuous coastal plain reduced by erosion to a more or less uniform base level extending westward from the eastern limits of the present continental plateau to the foothills of the mountains. A glance at any good map of this region will reveal the fact that the entire coast line, more especially to the northward of Charleston, is deeply indented by numerous shallow sounds and bays, like Delaware and Chesapeake Bays in the north and Albemarle and Pamlico Sounds farther south, while the country for many miles inland from the coast frequently consists largely of more or less impenetrable

marshes, such as the Dismal Swamp in Virginia and North Carolina and others bordering the lower courses of the James, Roanoke, Cape Fear, Pedee, Neuse and Savannah rivers, and to a less extent the Potomac, Susquehanna and Delaware rivers farther north.

If we trace the courses of the larger rivers of this region, those rising in the Appalachians, from their sources to their mouths, the course of each will be found to be divisible into three sections, when considered according to the eroding and transporting power of the stream. The first of these three sections, commencing above, extends from the source of the stream to the point where it leaves the foothills of the mountains and emerges upon the coastal plain. Throughout this portion of its course the stream is both an eroding and a transporting agent, displaying about equal efficiency in either capacity. Below this point, which has been called the "Piedmont escarpment," the stream ceases to be to any great extent an eroding agent, and between the foothills and the swampy region bordering the coast it is chiefly a transporting agent, the current being too sluggish to accomplish any appreciable amount of erosion, and at times becoming so slow as to permit of considerable deposition. Between that point where it enters the marsh lands and its mouth the stream drops all that remains of its load of sediment, save that which is carried seaward by the action of the tides, aided to some slight extent perhaps by the feeble current of the stream, which has now become almost entirely an agent of deposition.

Now if we turn our attention to the changes that are taking place in the region traversed by these rivers, it will be seen that the first section, or that between their sources and the Piedmont escarpment, is one almost exclusively of degradation, there being little or no deposition going on in this region, while throughout the second section, that lying between the escarpment and the swamps along the coast, the eroding and depositing agencies are unimportant, though about equally effective, resulting on the whole in comparatively little change in the topography, while in the third region, or that lying between the swamps and the coast, deposition is taking place with considerable rapidity. The inland swamps are being filled in, while along the coast of Virginia and North Carolina the estuaries and sounds located at the mouths of the various rivers or enclosed between the mainland and the low sand spits, thrown up by the waves and extending almost continuously along the coast,

are receiving vast quantities of material from the numerous streams emptying into them and are destined at some future time to be converted into fresh-water swamps like those now found inland, while the coast will be pushed farther eastward, repeating the same or very similar conditions.

If now we examine the material that is being deposited at various localities, commencing with that point on the coastal plain where deposition is more rapid than erosion, and extending eastward not only to the coast line but beyond to the eastern border of the continental plateau, we shall find that deposits of every character, from fresh water to estuary or brackish, littoral and purely marine, are being formed simultaneously, in each of which are preserved remains of the life characteristic of the conditions attending its deposition. In the swamps will be found peat bogs and beds of sand, clay and marl, with remains of terrestrial and fresh water vertebrates and invertebrates. Over the river bottoms will be found fluviatile deposits. In the estuaries, bays and sounds beds with the remains of a brackish water fauna are forming. Outside the sand spits that enclose Albemarle and Pamlico Sounds will be found other beds of sand with a littoral fauna. Still farther seaward and continuing to the limits of the submerged continental plateau a typically marine deposit is being laid down with remains of its characteristic fauna. Beyond this we reach the abysmal depths of the ocean with a fauna and deposit distinct from any of the others mentioned. Assuming that the average depth of the ocean just west of the eastern border of the continental plateau is 3000 feet, and that the western limit of true marine conditions extends to within fifty miles of the eastern limit of true fresh water or terrestrial conditions, we have then within a distance of fifty miles from east to west every character of deposit from terrestrial and fresh water to true marine forming at the same time; and if we continue our section to the eastern limit of the continental plateau, at altitudes differing more than 3000 feet from one another, as indicated by the curved line *a. a'.* which in the accompanying diagram, seen in figure 1, represents an imaginary line drawn along the surface of the ground and bottom of the sea from the western border of the swamps lying west of Pamlico Sound in North Carolina, across this sound and eastward to the eastern border of the continental plateau. Along this line *a.* to *b.* is the swamp region with fresh water deposits, *b.* to *c.* Pamlico Sound with its estuary depos-

its, *c.* to *d.* the shallow water and littoral deposits extending eastward from the coast, *d.* to *a.'* true marine conditions.

Let us suppose present conditions to continue without any elevation or depression of the earth's surface in this region, until by the process of erosion and deposition the present coast line is advanced to a position approximating that of the eastern limits of the continental plateau, as shown in the curved line *a.'–a.''* We would then have deposited between the lines *a.–a.'* and *a.'–a.''* sediments aggregating in vertical thickness something more than 3000 feet, and comprising four formations more or less distinct when considered from their faunal and lithological characters but of the same age, all four having been laid down in the same time interval and all conformable with one another save for an unconformity by

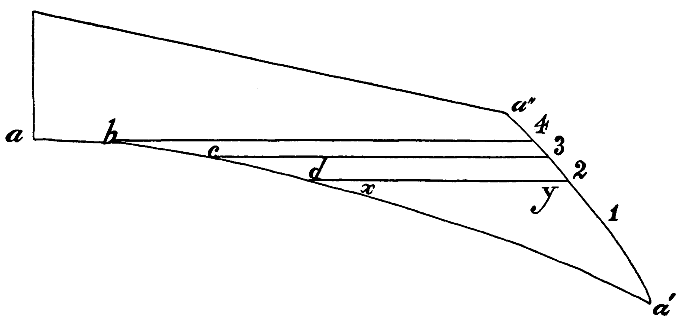


Fig. 1.

overlap along their western borders necessitated by the topography existing at the time when present conditions were inaugurated. Commencing below, No 1. of these four formations would be the thickest of the series and would form a wedge of purely marine and deep water deposits at the base with the blade directed westward. Above these deep water deposits would come No. 2 of the series, a marine shallow water and littoral deposit of nearly uniform thickness, which would be determined by the depth of water at which such deposits may take place. This would contain a littoral fauna and would overlap the western border of No. 1. Above this and overlapping it on the west would come No. 3, an estuary formation with its beds of oysters and other brackish water mollusca, now occurring in such abundance in the sounds and bays of this coast. The vertical range of these brackish water deposits, like that of No.

2, would, of course, be limited if, as we assumed above, perfectly stable conditions of the earth's surface were maintained in this region during the entire period required for the eastward extension of the coast line from its present position to that of the eastern border of the submerged continental plateau. Above No. 3 would come No. 4, the uppermost of the series, a fresh water and to some extent aeolian deposit, with its beds of peat transformed perhaps into lignite and remains of a terrestrial and fresh water vertebrate and invertebrate fauna. The thickness of these fresh water deposits would not be limited as would that of Nos. 2 and 3 of the series, since as the coast line advanced eastward it would leave behind a low and flat region growing continually wider from east to west and increasing very slowly in elevation by the accumulation over its surface of fluvial, lacustrine and aeolian deposits. As the width of the coastal plain increased the inclination of its surface toward the sea would become less and less and the drainage or run-off would be reduced to a minimum, transforming the region into one of lakes and marshes connected by sluggish streams and increasing its capacity for the accumulation of fresh water and aeolian deposits. By the uninterrupted continuance of such conditions these deposits would go on accumulating over this entire region long after the shore line had advanced far to the eastward of its present limits, resulting in a greater thickness of fresh water and aeolian deposits along the western than along the eastern border. These deposits would therefore form an overlying wedge with the blade directed eastward, or in a direction opposite to that of the wedge of marine deposits constituting No. 1 at the base of the series, and tending to produce a somewhat uniform thickness of the combined series of beds, with the fresh water deposits predominating in the western region and the true marine deposits in the eastern, while the interstratified brackish water and littoral deposits would continue practically of the same uniform thickness from the eastern to the western border of the region.

Thus far we have only considered what would take place here under perfectly stable conditions in the earth's crust. Let us next consider what would result from certain oscillations in the earth's surface along this coast.

If a period of elevation should set in affecting the coastal plain and submerged continental plateau the effect would be to hasten the recovery of the continental plateau from the sea and to decrease

the thickness of the various deposits forming in this region. Moreover, if the elevation to the westward should become appreciably more rapid than to the east the run-off would be increased by the greater inclination of the surface toward the sea, and a period of erosion would be inaugurated over a considerable portion of that area where formerly fresh water deposits were being formed.

If on the other hand the region should undergo a general but gradual subsidence, so gradual that the rate of upbuilding by deposition would be more than sufficient to keep pace with the subsidence, the result would be a lengthening of the time necessary for the coast line to advance eastward from its present position to that of the eastern border of the continental plateau and a corresponding increase in the thickness of the various deposits. Under such conditions the thickness of the littoral and estuarine or brackish water deposits would not be so restricted as under those conditions previously considered, but these might attain to almost any depth, varying in thickness at any given point according to whether the rate of subsidence during the deposition of these deposits at such point approximated or fell far below the rate of sedimentation taking place there. The more nearly the rate of subsidence approximated that of sedimentation at any point where littoral and brackish water conditions prevailed, the greater would be the length of time necessary to recover the area from the sea and the greater the thickness of the littoral and brackish water deposits.

If at any time the rate of subsidence exceeded that of sedimentation, conditions would immediately be reversed, the sea would encroach upon the land, the coast line would recede to the westward, and the fresh water beds seen at No. 4 in the diagram would be overlaid first by a brackish water deposit, over which would be laid down a littoral deposit, followed later by beds of deep water origin as the subsidence increased and the sea advanced upon the land. If this period of more rapid subsidence were only temporary it would result merely in a local interstratification of fresh water, brackish and marine deposits. If on the other hand it became permanent it would result in the entire resubmergence of the region already recovered from the sea, and there would be a repetition in reversed order of the fresh water, brackish, littoral and true marine deposits already described as having been formed during that period when the land was advancing upon the sea. At the close of his period of subsidence, when the sea had regained its original

shore line, a section through the deposits formed before and during this period would exhibit a structure similar to that shown in the second diagram, where *A.* represents a wedge of fresh water deposits immediately overlaid and underlaid by the brackish water beds *B. B.*, followed above and below by the littoral deposits *C. C.*, which are in turn underlaid and overlaid by the true deep water marine beds *D. D.*, and the time interval during which the single fresh water formation represented by *A.* was deposited will have equaled that employed in the deposition of the underlying and

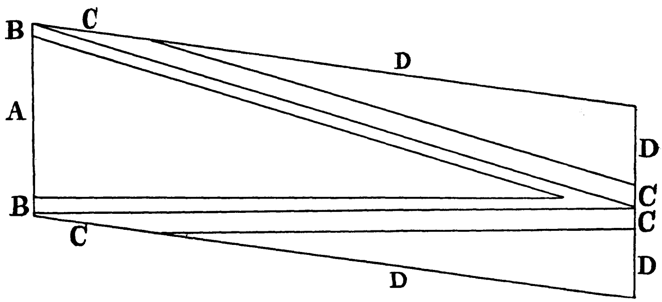


Fig. 2.

overlying marine and brackish water beds combined. The fresh water beds should, therefore, be correlated with both the underlying and overlying marine beds.

The actual conditions at present existing along our Atlantic coast, together with the possible results following a long continuance of these conditions, with variations similar to those outlined above, have evidently been repeated at certain intervals in Mesozoic times throughout our Middle West.

The Judith river beds at about the middle of the Upper Cretaceous, together with the overlying and underlying marine formations, known respectively as the Pierre or Bearpaw shales and the Claggett formation, form a splendid example of the conditions illustrated in the second diagram. They are composed of a series of deposits for the most part of fresh water origin, but overlaid and underlaid by brackish water beds. They attain to a known thickness of something over 500 feet and extend continuously from the Saskatchewan river region in Canada to southern Montana. They are well developed along about the 110th meridian of west longitude, where they may perhaps be regarded as attaining their maxi-

mum thickness. Some distance to the eastward of this meridian, however, they decrease in thickness and finally disappear, passing into the overlying and underlying marine beds mentioned above. In the second diagram *A.* would represent the fresh water and middle portion of the Judith river beds, *B. B.* the underlying and overlying brackish water beds usually referred also to the Judith river formation, while *C. C.* and *D. D.* inclusive would represent the Bearpaw shales at the top and the Claggett formation at the bottom, *C. C.* representing littoral deposits or passage beds from brackish water to true marine deposits and occurring everywhere throughout this region both at the top and bottom of the Judith river beds.

Having now seen how two or more formations occurring in regular sequence one above the other may originate simultaneously instead of pertaining to different and distinct ages, let us next consider what bearing this will have on the relative age of different horizons in any one of these formations. To the paleontologist this is an important point, since in working out the phylogeny and relations of fossil forms within the same formation it is often of the greatest importance to know whether a given genus or species preceded or succeeded another, or if the two were contemporaneous. Heretofore we have been inclined to consider any given stratum within a formation as having been deposited near the beginning, at about the middle or near the close of that time interval during which the formation was laid down, according to whether it occurs near the top, in the middle or near the bottom of the formation and regardless of the geographical position of that point at which the stratigraphical determination was made. To say that two fossils were found fifty feet beneath the top of a given formation which had not been subjected to erosion, but at a distance from each other of several, perhaps many miles, has usually been regarded as establishing for them an identical or very similar age. Every consideration has been given to the stratigraphic position, none to the geographic. Yet in not a few instances the latter is of equal or even far greater importance than the former, and must be considered in determining at just what period in the time interval necessary for the deposition of a certain formation any given stratum was laid down. Furthermore, we have been accustomed to estimate the time employed in the deposition of any given formation solely by its vertical thickness, and regardless of its geographical

extent assuming that conditions were more or less uniform over the entire region occupied by the formation from the beginning to the close of its deposition—an assumption wholly unwarranted, as we have seen in formations deposited under conditions similar to those represented in the first diagram and more especially in the littoral and brackish water beds, represented respectively by 2 and 3. In beds such as these the actual area over which deposition takes place at any given time is limited to a narrow strip along the coast, and materials are there being added simultaneously and continuously throughout the entire vertical extent of both these beds. It is thus evident that in deposits such as these geographical distribution rather than vertical thickness is the basis upon which to estimate the length of time employed in their deposition. The age of any fossil found in these beds will be greater or less than that of another found at a different locality, not according as to whether it occurred at a higher or lower level in the series, but according to the difference in the geographical position of each relative to the original coast line, and the actual difference in age will, of course, depend upon the difference in the geographical positions at which the two occurred and the rate of advance or recession of the coast. The difference in age would be expressed in years by dividing the distance between the two localities, measured along a line at right angles to the original coast line, by the annual rate of advance or recession of the coast.

Let us consider again the conditions at present existing along our Atlantic coast and represented in the first diagram. It will be readily apparent that as the coast line is advanced eastward by the deposition of the material brought down by the streams, the western limits of true marine, littoral and brackish water conditions will be more and more restricted and that marine conditions with a depth of sea of more than 2000 feet will prevail over the region near the eastern border of the submerged continental plateau long after the present coast line has advanced to the position shown at *X.* on the diagram, while to the westward of this position the region has all been brought above sea level and only fresh water and aeolian deposits are being formed. It is evident then that when the coast line has been advanced to *a.*″ the uppermost stratum of the marine formation, No. 1, will not be of uniform age from *X.* to *Y.*, but that this stratum at *X.* will exceed in age the same stratum at *Y.* by the length of the time required for the

coast to advance from *X.* to *Y.*, represented at *Y.* by a vertical thickness of deposits of about 2000 feet.

With the overlying brackish water and littoral formations represented by Nos. 2 and 3, the stratigraphic position of any horizon at any locality within either would be of minor importance in determining its age relative to the formation as a whole. Since the deposition of these beds would not take place simultaneously over the entire area of their distribution, but would be restricted to a narrow belt along the coast which would move eastward as the coast advanced, it is evident that these deposits would be oldest to the west and newest toward the east. This is an instance where geographical position is of far more importance than stratigraphical in determining the relative age of a given stratum within a formation.

From the above observations it appears to the present writer that other elements than their present stratigraphic position relative to one another must be considered in determining the age and in correlating any series of formations deposited along a receding or advancing coast. There is evidence that several of the Mesozoic formations of our Middle West were deposited under such conditions. It should first be determined whether the sea was advancing or receding during the deposition of any given series. Next the direction taken by such advance or recession of the sea should be ascertained, in order to determine in what geographical position the older beds of the series are to be found. Then the rate of deposition as compared with the rate of advance or recession of the sea should be determined, so as to be able to correlate with one another, approximately at least, strata within the same formation but occupying different geographic and stratigraphic positions. In the following attempt to correlate various formations in the region referred to the methods and principles outlined above have been applied only in a very general way, and the results can only be considered as suggestive of what might be accomplished by more extended observations and careful determinations in the same region.

The Atlantosaurus Beds and Dakota Sandstones considered as the possible equivalents of the Upper Jurassic and Lower Cretaceous.

There is a considerable thickness of non-marine sandstones and shales with a wide geographical distribution in the region under question, concerning the age of certain members of which there has been much difference of opinion. The lower member of these was

first differentiated by Marsh who named them the *Atlantosaurus beds*.[1] They have since received various other names by other authors, such as the Como beds, the Morrison beds, the Beulah shales, etc. Since these later names are no more appropriate than the one first given there is no good reason for accepting any of them and rejecting the name first bestowed on these beds by their discoverer. Moreover, if stability in geological nomenclature be desirable there would seem to be no better way of securing it than by recognizing priority. It may be well to adopt certain rules governing the formation of new names for new formations, but these rules should not be made retroactive in their application, since such application will not only fail to do full justice to many earlier geologists but, what is of far more importance, will result in increasing still further that synonymy already existing in our geological nomenclature.

In their typical exposures the Atlantosaurus beds consist of rather fine shales. At certain localities there are in them occasional small lenses of limestone with fresh water invertebrates and more important lenses of sandstones frequently appearing as distinct and quite continuous strata. Toward the top the sandstones become more frequent and the whole is everywhere overlaid by a heavy bed of sandstone known as the Dakota sandstones, save where these have been removed by erosion. In some places the passage from the sandstones and shales of the Atlantosaurus beds to the Dakota is quite abrupt, but as a rule it is very gradual, the two grading into one another in such manner that it is difficult to say where the one ends and the other begins. Both these formations are of fresh water and aeolian origin, though there is evidence of brackish water or littoral deposits in a few places near the top of the Dakota.

The Dakota sandstones have usually by general consent been considered as representing the base of the Upper Cretaceous, both from their stratigraphic position beneath the Benton and from their fossil flora. The latter, however, can scarcely be considered as being at present at least of any special value in determining the exact age of these sandstones, which in many places in the western portion of the region under consideration pass insensibly below into the sandstones and shales of the Atlantosaurus beds. In the region near Buffalo Gap, S. D., Darton has distinguished these transitional

[1] The *Hallopus beds* of the same author are disregarded here as of minor importance and being usually not distinguishable.

beds as the Lakota formation and has discovered in them dinosaurian remains representing types differing from and distinctly more recent than those commonly met with in the typical Atlantosaurus beds. Moreover at several localities these transitional beds have yielded cycads and other plant remains which, according to Prof. L. F. Ward who has studied this flora, are of Lower Cretaceous types. At present the dinosaurian fauna is too meagre to determine certainly whether its affinities are with the Jurassic or Lower Cretaceous. Its aspect is however, in so far as we know it, more modern than that of the typical Jurassic. The Predentata appear to be assuming the predominant position held throughout the Jurassic by the Sauropoda, and I am inclined to consider the dinosaurian fauna as indicative also of a Lower Cretaceous age for these beds.

The Atlantosaurus beds, consisting of dark shales with intercalated sandstones, have a wide distribution throughout the western portion of the region under consideration, where they appear at the proper position in the geological section encircling every mountain upthrust and occupying many of the intermediate valleys. These beds contain the remains of an exceedingly rich and varied dinosaurian fauna, concerning the age of which there has been some difference of opinion. At present, however, this fauna together with the beds containing it is very generally regarded as of Jurassic age. There are, however, certain geologists and paleontologists who still regard these deposits as of Lower Cretaceous age. The dinosaurs, which probably offer the most reliable evidences as to the age of these beds, are unmistakably Jurassic in type, whether the comparison be made between the individual species or the faunas as a whole. Marsh was wont to correlate the Atlantosaurus beds with the Wealden which he regarded as of Upper Jurassic age, but which is now usually placed at the base of the Lower Cretaceous. It is not quite clear upon what evidence Marsh relied when making this correlation. The dinosaurian fauna of the Wealden is certainly quite different and more modern than that of the Atlantosaurus beds. In the Wealden the Sauropod dinosaurs, which form such a conspicuous feature in the faunas of the Middle and Upper Jura, are on the wane and that group of Predentate dinosaurs known as the Iguanodontia has attained unusual importance, assuming to a certain extent at least the position formerly held by the Sauropoda. In the Atlantosaurus beds, however, the Sauropoda predominate and

the Iguanodont group of the Predentata are represented by smaller and less specialized forms. The dinosaurian fauna of the Atlantosaurus beds as we now know it is certainly more nearly allied to that of the Kimmeridge and the underlying Oxfordian than to the Wealden or the Purbeck, and there is little doubt that the true Atlantosaurus beds, those lying below the Lakota of Darton, are of Upper Jurassic age.

Throughout the northern area of their distribution the Atlantosaurus beds are conformably underlaid by a series of marine deposits variously known as the Baptanodon beds, the Shirley beds, the Sundance formation, etc., and universally referred to the Upper Jurassic. That these beds are of Upper Jurassic age has not been questioned and is abundantly confirmed by both their invertebrate and vertebrate faunas. About the Black Hills in South Dakota, the Big Horn Mountains in northern Wyoming, and at other places these marine beds attain a considerable thickness, 400 to 500 feet, while the overlying Atlantosaurus beds of fresh water origin show a more restricted development in these regions than they attain farther to the southward. As we proceed southward, however, the marine deposits diminish in thickness and disappear altogether near the boundary line between the States of Colorado and Wyoming. Farther south the Atlantosaurus beds attain to a maximum thickness of perhaps 500 feet and rest directly but unconformably upon the "Red Beds," now usually considered in their upper members at least as of Triassic age, but formerly referred to as the Jura-Trias. Still farther south in New Mexico, Lee has found conditions which lead him to believe that these fresh water beds are continuous with marine beds of Lower Cretaceous age pertaining to the Comanche series. Though the evidence is at present not at all conclusive and nothing is known concerning the character of the vertebrate fauna of the fresh water beds at this locality beyond the fact that they contain dinosaurian remains, yet it is quite possible that the upper members of this series, the Lakota of Darton, may pass eastward into true marine deposits of Lower Cretaceous age.

To the eastward the Dakota sandstones, at the summit of the series of fresh water and aeolian deposits under discussion, overlap the underlying Lakota sandstones and Atlantosaurus beds, and in eastern South Dakota, Nebraska and Kansas they rest unconformably upon strata pertaining to the Carboniferous or Permo-Carboniferous.

From the foregoing remarks it will appear that in the region referred to in the title of this paper there is a conformable series of marine and fresh water or in part aeolian deposits, commencing below in the north with marine beds unquestionably of Jurassic age and passing upward and toward the south and east into a series of fresh water and aeolian deposits containing a dinosaurian fauna, with affinities clearly allying it also with the Upper Jurassic and another still later horizon, the Lakota of Darton, with a Lower Cretaceous flora and a dinosaurian fauna of the character of which as yet little is known, but which is certainly more recent than that of the true Atlantosaurus beds, the entire series terminating above in the Dakota sandstones generally referred to the base of the Upper Cretaceous. This entire series rests unconformably upon the "Red Beds" in such manner as to show conclusively that prior to the beginning of its deposition there was in this region a long and continued period of erosion, embracing perhaps the close of the Triassic and a considerable portion of the Jurassic. At the top the Dakota sandstones are overlaid with apparent conformity by the Benton, the lowermost marine member of the Upper Cretaceous. As yet no evidence has been advanced to show that sedimentation was not continuous in this region from that period which marked the beginning of the deposition of the marine Baptanodon beds at the base of the series to the close of that much later period which witnessed the deposition of the Dakota sandstones, and I see no reason why this series of deposits may not represent in this region the entire Lower Cretaceous and Upper Jurassic, as their floras and faunas and the stratigraphy and conditions of sedimentation would seem to indicate. I am well aware of the enormous time interval which a correlation such as that just suggested presupposes for the deposition of this comparatively meagre series of deposits, aggregating a thickness nowhere of perhaps as much as 1000 feet and in no way comparable with the thousands of feet of beds which in other regions are known to be included in the Lower Cretaceous alone, to say nothing of the Upper Jurassic. Nevertheless this objection does not seem an especially important one when we consider the wide geographical distribution of those non-marine deposits which constitute by far the greater bulk of this series, and the time interval necessary for the deposition of which, as we have seen at the beginning of this paper, should be estimated not so much by their vertical thickness as by the extent of their geographical distribution.

Non-Marine Equivalents of the Marine Beds of the Colorado and Montana Formations.

Between the Dakota sandstones and the base of the Tertiary there is in this region a number of formations the characters of which are indicative of littoral, brackish, fresh water and terrestrial conditions.

The lowermost of these is the Eagle formation, consisting for the most part of massive sandstones with intercalcated beds of lignite and shales. This formation is known to have a considerable distribution in Montana and it doubtless extends northward into Canada. In general it is not very fossilferous, but in places, usually of very limited extent, it has been found to contain in considerable abundance marine invertebrates, indicative of littoral conditions. Although as yet no fresh water vertebrate or invertebrate remains have been found in these beds, yet the nature of the materials composing them and the manner in which the sandstones, shales and lignites replace one another are indicative of an adjacent land mass, and it is quite probable that they are to some extent at least of fresh or brackish water origin. A few remains of terrestrial vertebrates have been found in them. They afforded the type of *Ornithomimus grandis* Marsh and other fragments of terrestrial dinosaurs. The presence of these remains may be considered as additional evidence of an adjacent land-mass.

The Eagle formation is conformably underlaid and overlaid respectively by the Benton and the Claggett formations. Its stratigraphical position is nearly, perhaps identically, the same as that occupied by the Niobrara farther to the southeast, and it was I think quite properly correlated with that horizon by Mr. Earl Douglass, though I should not be in favor of applying the same name, as was done by Mr. Douglass, to formations so different in lithological and faunal characters. From the nature of these deposits it is evident that toward the close of the Benton there was in this region a decided change of conditions which materially altered the character of the sedimentation, and that the true marine conditions which had prevailed continuously throughout the Benton gave place to at least shallow waters and in part perhaps to brackish and terrestrial conditions, though it is evident from the character of the beds composing the Eagle formation that the transformation was by no means so complete at this interval as during the preceding one which witnessed the deposition of the Atlantosaurus beds and

Dakota sandstones, or the two succeeding intervals marked by the deposition of the Judith river beds and the Laramie.

After the deposition of some 300 to 400 feet of the sandstones, shales and lignites of the Eagle formation true marine conditions were again restored in this region. That this return to marine conditions was gradual and due to a slow advance of the sea over the region in question is evidenced in certain places by the manner in which the uppermost Eagle sandstones pass by a series of shales and lignites into the overlying true marine beds of the Claggett formation, and is well shown on Eagle Creek a short distance above where it empties into the Missouri river, some twenty miles above Judith, Mont., at a place which may be regarded as the type locality for the Eagle formation.

Although we have not been able to trace this formation continuously to the east and south and to observe its actual passage in those directions into the overlying and underlying marine formations, yet we do know that it disappears in these directions and is entirely replaced by marine deposits resembling those of the Niobrara and the base of the Montana. From all the evidence at hand it seems probable that over the region now occupied by the Eagle formation shallow water and in part terrestrial conditions prevailed for a considerable period, commencing toward the close of the Colorado and continuing uninterruptedly well up into the Montana, and that this formation should be correlated with the upper portion of the Colorado and the lower portion of the Montana.

After the deposition of the Eagle formation marine conditions again prevailed over this region, as is evidenced by the 300 to 400 feet of characteristically marine deposits known as the Claggett formation intercalated between the Eagle sandstones and the Judith river beds. From the nature of the deposits constituting the Claggett formation it is evident that this return to marine conditions was not so complete as it had been in the Benton, for at intervals in the Claggett there are beds of sandstones with marine invertebrates, indicative of shallow water or littoral conditions. These are especially prevalent toward the top, where they may be regarded as prophetic of that return to terrestrial conditions which was soon to follow and which witnessed the deposition of the overlying 500 to 600 feet of non-marine deposits known as the Judith river beds. As remarked earlier in this paper the passage from the Claggett formation to the Judith river beds is in most places extremely

gradual, as is also that from the latter to the overlying marine deposits known as the Pierre or Bearpaw shales. In the first instance there is abundant evidence of the gradual replacement of marine conditions by non-marine, commencing below with littoral and brackish water deposits and terminating above with beds indicative of typical fresh water and terrestrial conditions, while in the second instance the evidence is equally conclusive of a gradual replacement of terrestrial by true marine conditions. As with the Eagle formation the Judith river beds continue for some distance to the south and east, but decrease in importance and are finally entirely replaced by marine deposits now universally referred to the Pierre or Montana group of the Upper Cretaceous. It is evident therefore that the Judith river beds in their typical development represent deposits that were contemporaneous in origin with these marine beds farther to the southeast and that they should be correlated with them.

Overlying the Judith river beds but partly contemporaneous with them in origin is the series of shales already mentioned as the Pierre or Bearpaw shales. These are true marine deposits and pass upward through the Fox Hills sandstones into that great series of brackish, fresh water and aeolian deposits aggregating from 2,000 to 3,000 feet in thickness and known as the Laramie formation. The passage from the Pierre to the Laramie is everywhere very gradual, and the evidence is so strong as to be almost conclusive that there was in this region a gradual advance of the land upon the sea resulting finally in the recovery of the entire area from the latter. Considering the enormous extent of the area which marks the present distribution of the Laramie, a very great length of time must have elapsed between that period when the first portion of this region began to appear above the level of the sea and that later period which marked the final recovery of the entire region. The length of this period is also indicated to some extent at least by the difference in the character of the brackish water faunas that in various and widely separated localities are found in beds immediately overlying the Pierre-Fox Hills[1] and which would have been contemporaneous had brackish water conditions been

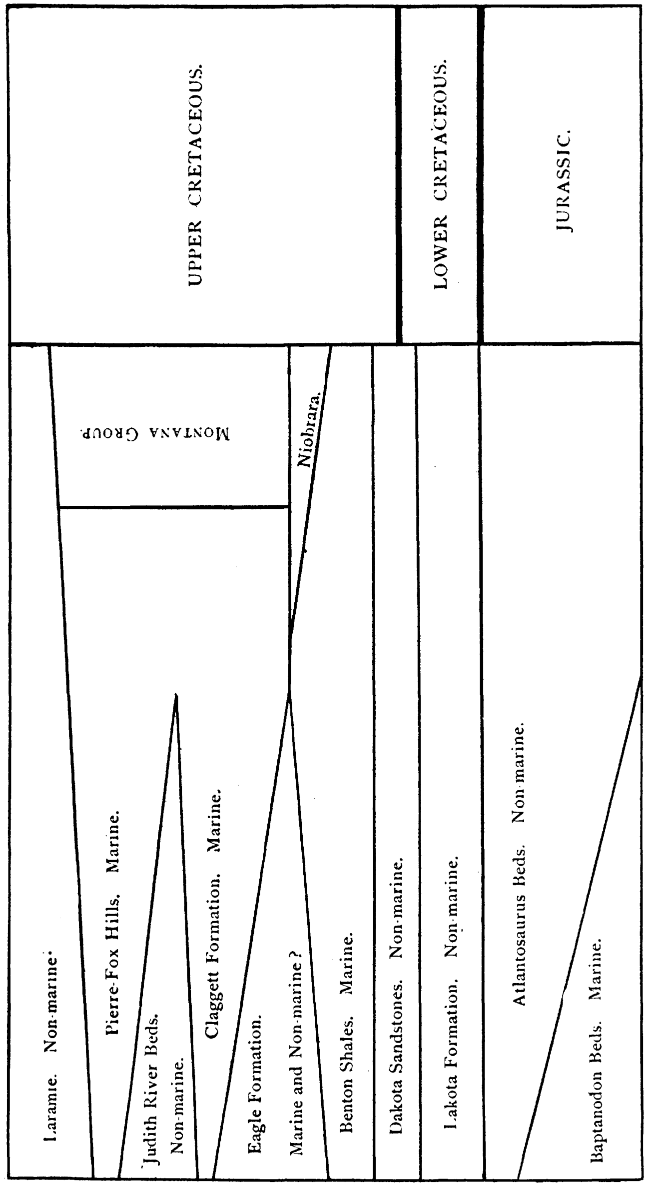
[1] This sentence was written with the idea that the Bear River fauna of Western Wyoming really belongs to the Laramie, as was once generally believed. It is now known to belong to an entirely different horizon, and this statement was agreed to by Mr. Hatcher at the time of our discussion.—T. W. S.

brought about simultaneously over this entire region, conditions however which are absolutely prohibited by any even fairly reasonable hypothesis. It seems quite reasonable therefore to suppose that the early Laramie was largely contemporaneous in origin with the later Pierre, and were the geological records complete it is not impossible, and I may say improbable, that somewhere to the westward of the 110th meridian the wedge of Pierre shales interposed between the Judith river beds below and the Laramie above would thin out and become entirely replaced by these two formations, just as the Judith river beds below pass into the overlying and underlying marine deposits to the eastward of that meridian.

From the nature of the terrestrial and fresh water vertebrate and invertebrate faunas of the various deposits represented in this region, from the base of the Atlantosaurus beds below to the summit of the Laramie above, it is evident that somewhere in this region or adjacent to it terrestrial and fresh water conditions prevailed continuously throughout this entire period though perhaps not in any one locality. Although we have at present only a partial record of such terrestrial conditions it is probable that the record may be still further perfected by the discovery of remnants at least of other non-marine formations.

From the above remarks it will, I think, have been made clear that the various non-marine Jurassic and Cretaceous deposits of our Middle West do not necessarily represent time intervals distinct from those which witnessed the deposition of the marine beds of the same region, but that marine and terrestrial conditions existed simultaneously and more or less continuously, each giving origin to its peculiar deposit. It thus happens in this region that every non-marine deposit, save the uppermost Laramie, has its marine equivalent with which by careful study it may be correlated, and the following diagram[1] is submitted as representing the author's present views as to the proper correlation of these deposits.

[1] The diagram as originally prepared has been altered slightly, as follows: The Laramie is made to extend over the Montana group; the Claggett formation is made to blend with the Pierre-Fox Hills beyond the limits of the Judith River beds; and the Niobrara is interpolated between the Benton shales and the Montana group. These changes make the diagram agree with the text.—T. W. S.


UPPER CRETACEOUS.
LOWER CRETACEOUS.
JURASSIC.
Montana Group.
Niobrara.
Laramie. Non-marine.
Pierre-Fox Hills. Marine.
Judith River Beds.
Non-marine.
Claggett Formation. Marine.
Eagle Formation.
Marine and Non-marine?
Benton Shales. Marine.
Dakota Sandstones. Non-marine.
Lakota Formation. Non-marine.
Atlantosaurus Beds. Non-marine.
Baptanodon Beds. Marine.

The points which it is especially desired to emphasize in the preceding pages are the following:

1. *That stratigraphic position is not the only factor to be considered in determining the relative age of geologic formations.*

2. *That an overlying deposit may have been contemporaneous in origin with that immediately underlying it instead of more recent.*

3. *That in determining the relative age and working out the phylogeny of fossil forms the geographical position at which they occur in a given formation is frequently of greater importance than the stratigraphic.*

4. *That the determination of the approximate time within a given period at which any stratum was deposited is often a more complicated problem than has been generally supposed and cannot always be estimated by its position relative to the base or summit of the series.*

5. *That every correlation should be based when possible on stratigraphy, aided by the contained fossils and an interpretation of those physical conditions attending the deposition of the beds in question.*

6. *That further studies are necessary relating to the physical conditions that prevailed and the changes that were taking place over the region occupied by the formations discussed above during the period of their deposition before we may hope to attain even a fairly satisfactory correlation.*

NOTE.

Justice to the memory of my much lamented friend, J. B. Hatcher, impels me to state my belief that had he lived he would not have published the above paper without considerable revision and alteration. The ideas that he has here attempted to express were largely suggested or confirmed by the field study of the Judith River beds in coöperation with the present writer during the summer of 1903. A preliminary statement of our results has already been published[1] and a fuller account, which will shortly appear as a bulletin of the U. S. Geological Survey under the title "Geology and Paleontology of the Judith River Beds," was written by Mr. Hatcher and myself last spring. On account of this association and of my familiarity with the region and formations under discussion, Hatcher came to me with his manuscript immediately after reading it in Philadelphia and invited criticism. At least one other friend

[1] *Science*, n. s., Vol. XVIII, pp. 211–212, Aug. 14, 1903.

in Washington also read it. Hatcher and I spent an evening in earnest, friendly discussion, at the close of which he stated that on some points he had evidently not expressed his ideas clearly, while on others his views had been modified, and that he would seek further criticism from some good stratigrapher and would revise his manuscript thoroughly before publishing it. Evidently he never found time for the revision as he did not change the manuscript in any particular.

There is certainly a lack of clearness of expression, which seems to me due to confusion of ideas, in the repeated statements that imply that stratigraphic sequence in undisturbed deposits does not necessarily mean chronologic sequence. As an example the second of Hatcher's emphasized conclusions may be quoted: "That an overlying deposit may have been contemporaneous in origin with that immediately underlying it instead of more recent." Obviously he did not mean to assert that in any actual exposure one stratum is contemporaneous with another on which it rests, or with still another above it. That would be contrary to the fundamental principle of stratigraphic and historical geology, and Hatcher repeatedly denied that he intended to express any such ideas. He meant rather that distant exposures holding the same apparent position in a formation laid down along a changing coast may not be strictly contemporaneous, and that a formation may be overlain or underlain by deposits similar to those formed simultaneously with it in another area. Thus when he says that the Pierre shales overlie the Judith River beds but are partly contemporaneous with them in origin, he refers to the fact that the Pierre shales in one area form an undivided marine formation which includes the equivalents both of the Judith River beds and of the overlying marine beds which we have designated as the Bearpaw shales. The confusion is caused by calling a part of a formation by the same name as the whole.

Mr. R. T. Hill has long ago suggested that the Dakota sandstone was a littoral formation laid down while the sea was trangressing the land from Texas, Kansas and Nebraska to the Rocky Mountain region, and that it may represent in different parts of the area a much longer time interval than its thickness would indicate. The same author gives a still better example in his discussion of the "Basement Sands" of the Lower Cretaceous, which, he says,[1]

[1] *Twenty-first Ann. Rep. U. S. Geol. Survey*, Pt. VII, pp. 132, 133.

"are undoubtedly of shallow-water or near-shore origin and represent the ancient marginal deposits of the sea as it encroached upon the land. Everywhere, next to the Paleozoic floor and conformable to its slope, this bed of sand, which seldom reaches 200 feet in thickness, persists as an apparent formation, blanketed between the underlying Paleozoic floor and overlying calcareous beds, and inclines toward the sea at a slightly greater angle than the latter.

"While these Basement sands of the Cretaceous, both in the area of outcrop and in that of the embed penetrated by the deepest wells, have the aspects of a continuous formation, they are in fact the interior margin of many formations, and were in process of deposition during a long period of time, and their successive layers are of later and later age as one descends the slope of the old Paleozoic floor."

The whole discussion from which these sentences are quoted is a clear description of an apparently continuous deposit which is not of the same age in different parts of its area, and which is thus an illustration of the principle that Hatcher especially emphasized. Such conditions are exceptional, however, and it by no means follows, as Hatcher seems to have supposed, that all, or even most, littoral and non-marine formations were extended only by accretions along their borders, and consequently that if they cover any considerable area the time required for their deposition is proportionally long, or, to quote Hatcher's words, that the time interval "should be estimated not so much by their vertical thickness as by the extent of their geographical distribution." In cases like those above cited it is usually possible to determine the true character of the deposits and to form some idea of the time interval represented by them by studying the associated formations. If a conformably overlying formation is the same throughout the area occupied and shows no change in paleontologic contents, we must conclude that the interval represented by the upper layers of the deposit in question is brief in a geological sense, although we may be convinced that the deposits at different localities were not strictly contemporaneous when measured by the smaller time units of human history. The fact that in certain cases a formation may not be strictly contemporaneous throughout its geographic extent is not denied, but the relative importance of this fact in its bearing on paleontologic and stratigraphic work is questioned. In my opinion it is greatly exaggerated in the third of Hatcher's conclusions.

Concerning two important assumptions in Hatcher's argument we could not reach an agreement: (1) That the continuance of present conditions along the Atlantic coast would result in such a succession of formations as is represented by Fig. 1; and (2) that the conditions now obtaining along this coast are comparable to any considerable extent with those of the Middle West in Mesozoic time.

The diagram (Fig. 1) was of course intended only as a crude illustration of the author's ideas. Granting that the littoral deposits might extend progressively seaward over the true marine beds, it is scarcely conceivable that the sediments laid down in brackish and fresh waters could constitute continuous formations across the entire area, nor that any great thickness of fresh water deposits could be built up above sea level on a coastal plain. Nor does it seem to me probable that even the littoral deposits laid down under such conditions would be treated as a single formation.

It is difficult to reconstruct the physiographic conditions that prevailed in the middle West during later Mesozoic time, but it should be remembered that there was then a great shallow continental or mediterranean sea, and that there were large areas so near sea level that very slight movements would bring them beneath the sea or partly or wholly drain them, so that it is probable that shallow water and non-marine conditions were often extended over large areas very rapidly. It should be remembered also that in speaking of the great geographic distribution of the resulting formations we are often dealing with their extension along a shore, or with contemporaneous deposits on opposite shores of the same sea. With such conditions it is easy to understand the many alternations of marine with non-marine formations, and it is recognized that both classes of deposits were formed contemporaneously in adjacent areas. This has made the geologic record of that region very complex, if not obscure, and it is still far from being completely interpreted.

The correlations indicated by the diagram have mostly been worked out by stratigraphic methods aided by paleontology, and agree with the present state of knowledge so far as the Upper Cretaceous is concerned. The treatment of the lower horizons is more tentative and represents Hatcher's opinions as stated in the text.

More detailed criticism and comment are unnecessary, although many minor points are subject to discussion. The whole paper is

full of suggestive ideas and again calls to mind the loss that geology has sustained in the untimely death of J. B. Hatcher. Had he lived he would have continued to make important contributions to the geologic history of the West, especially in connection with the problems concerning the non-marine formations whose importance he fully recognized and in which he was so deeply interested.

T. W. STANTON.

Washington, D. C., November 17, 1904.

THE MORPHOLOGICAL SUPERIORITY OF THE FEMALE SEX.

BY THOMAS H. MONTGOMERY, JR., PH.D.[1]

Read October 7, 1904.

It is remarkable the view should still generally obtain that the male sex is superior structurally to the female. This has resulted mainly from the fact that most writers upon sexual dimorphism have been males and, on the principle that charity begins at home, wished to give their sex all credit. Social economists in their ill-considered gleanings from Biology hold for the most part that the male is the superior, structurally and psychically, speaking of man as the "progressive" and woman as the "conservative" element of human society. But even if these terms are correctly applied, which is assuredly open to question, it does not follow that conservatism denotes inferiority and progressiveness superiority, at least from the morphological standpoint. Some naturalists share this opinion, though the facts are in patent contradiction to it; others grant the female is the superior in the lower animals, but not in the higher; most express themselves very decidedly that in the human species at least the male is the morphologically more perfect. It is a question of fundamental importance in any consideration of sexual dimorphism, especially in the valuation of the so-called secondary sexual characters. And should the common view be disproved, the relations of the sexes would show in a very different light; the male must be regarded as the inferior organism.

[1] Contributions from the Zoological Labratory of the University of Texas, No. 62.